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AN APPROACH TO DATA PROCESSING IN OPERATIONS COMMAND CENTERS

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by

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Submitted in partial fulfillment of
the requirements for the degree of

MASTER OF SCIENCE
IN
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ABSTRACT

The pursuit and attainment of our national objectives is largely supported by the capabilities of the Armed Forces. The ability to deter aggression, defend national sovereignty and maintain the position as a world leader depends upon proper decision making in the Command and Control system from the level of the President to the lowest echelon tactical commander. Automated data processing has been chosen as a method to assist the commander in a position of Command and Control to make his decisions. Underlying concepts of the Navy sponsored automated data processing system are described. The history and fundamental basic development of the system is presented to logically unite the fields of military professionalism and computer technology.

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1. Introduction

The pursuit and attainment of our national objectives is largely supported by the capabilities of the Armed Forces. The ability to deter aggression, defend national sovereignty and maintain the position as a world leader depends upon proper decision making in the Command and Control system from the level of the President to the lowest echelon tactical commander. M. O. Kappler explains a "Command and Control system" as [5]:

> ...a procedural system serving a military organization that has a job to do. The job may be logistics, combat or both. ... in modern warfare we are confronted with a very large operation where almost everything is out of the commander's sight. The complexity of the operation demands that information be reduced to symbols. These symbols have to be "communicated in" to the commander or the command group; records have to be made; displays have to be presented; decisions have to be made; and commands have to flow out. ...a command and control system exists whether one has machine computation and automated information or not.

The Department of Defense, as an executive arm of the President, has levied a requirement of continuity in Command and Control from the highest to lowest level of command in the armed services. Each service is responsible to the Secretary for this continuity within their commands as well as in the Joint Chiefs of Staff controlled commands which are assigned to the various services for their financial and material support.

Automated data processing has been chosen as a method to assist the commander in a position of Command and Control to make his decisions. This is not the only method but it is considered one with great potential. With the rapid growth of the computer field there has arisen the peculiar technical jargon that accompanies each profession and vocation. This jargon has a tendency to shroud the technological area with an aura of mystery which often misleads the

uninitiated. The advancement in computer applications has been within a very short time frame. This does <u>not</u> indicate, however, that the Navy has implemented an untried concept with which it has had no experience.

The purpose of this thesis is to present the underlying concepts of the Navy sponsored Command and Control automated data processing system to the constantly increasing group of personnel who are becoming associated with the commands utilizing it. Through knowledge of the history and the fundamental basic development of the system, the seemingly different and unrelated fields of military professionalism and computer technology can be logically united.

2. History of Computer Applications in the Navy

The U. S. Navy has been interested in military application of computers since their development. The first electronic digital computer, the ENIAC, was built by Mr. J. Presper Echert, Jr. and Dr. John W. Mauchly at the University of Pennsylvania in December, 1945 and used by the Army at Aberdeen Proving Grounds. Even before 1945 the Navy was interested sufficiently to sponsor the electromechanical computer research at Harvard University's Cruft Laboratory. Fittingly, the Harvard Mark I calculator was designed and constructed in 1944 by then Commander Howard Aiken, USN, in collaboration with International Business Machines Corporation.

The UNIVAC, a grandson of ENIAC, was developed by Echert and Mauchly for Remington-Rand in 1950 and was the first large scale computer to display the versatility and flexibility to handle alphabetic as well as numeric data. In December 1952, the Bureau of Ships established the Applied Mathematics Laboratory in its field activity, the David W. Taylor Model Basin. A UNIVAC was purchased and was installed and in operation by August 1953. The following seven years were marked by tremendous advancement in the computer field. The original mission of the Applied Mathematics Laboratory expanded as did their computing equipment. The Naval Ordnance Research Calculator (NORC) was installed at the U. S. Naval Proving Grounds, Dahlgren in 1954 and used by both the facility and the David Taylor Model Basic [3]. By 1960 an IBM 7090 and a Remington-Rand LARK were also installed at the Model Basin and in constant use.

The Naval interest in digital computers is essentially twofold. First is the use of a computer as a scientific tool in the solution

of equations and statistical problems pertaining to Naval engineering and logistic support. This thesis does not encompass this type of computer application but it is of sufficient importance to list examples of original problems undertaken [1]:

a. Mutual impedance between adjacent whip antennas aboard a submarine operating at periscope depth.

b. Radioactive fall-out for hypothetical patterns of attack, weapons yields, and wind conditions at designated areas in the United States.

c. Wind tunnel data to determine bending moments in wing surface under widely varying conditions.

d. Natural whirling frequencies and associated modes for the rotating propeller shafts of new aircraft carriers.

e. Nuclear reactor calculations for:

   (1) Approximate predictions of reaction behavior at various stages of burnout.

   (2) Determination of optimum lattice spacing and angular divisions.

   (3) Penetration of neutrons and gamma rays in a shield composed of alternate layers of iron and water.

f. Analysis of failure rates of electronic equipment on board naval vessels.

g. Allocation of military equipment to various fleet units considering factors such as military importance of ships, interchangeability of functions, locations of ships, and shipyard availability.

The second use of digital computers can be considered a sophis-

ticated form of data processing. This form, which in industry is often called a business application, best fits the needs of the Command and Control system of the Department of Defense. This use is primarily composed of the business type applications such as filing, sorting and retrieving both calculated figures and alpha-numerical data in such a manner as to present the best compilation of available data on which the commander can base his decisions. As a abundance of file material grows, manual and semi-automated retrievel of data pertinent to a particular requirement becomes increasingly difficult. The speed with which the data must be reduced ---made meaningful --- is so great in many instances that men -- any number of men -- cannot do the job manually. In addition, after such material has been assembled and filed, there are often requirements that it be rearranged in ways which can overlap each other.

It should not be interpreted that scientific and business computer applications always are separate and distinct. In the more sophisticated applications, they present poorly defined interfaces at which one application lends support to the other. One author states [11]:

> The data processing field has come a long way from the early stages of computer development when system application could be divided into the extremely simple classifications of "business" and "scientific" use.

Simultaneously with the rapid computer development came the realization that with modern weapons and drastically reduced response times, a commander needs the capabilities that can be provided only by today's high speed computers to aid him in his decision making role. The first computer project was the implementation of a sea surveillance system to cope with the probable surface and subsurface threats from

the seas to the Continental United States as recommended by the LAMP LITE report [1]. It was for the purpose of monitoring this specific project and research into other applications of automated data processing in the Command and Control area that the Operations Research Division (ORD) of the Applied Mathematics Laboratory of the Taylor Model Basin was formed in March 1958. Initial tasks were the feasibility studies to determine the practicality of computer use in such a critical field. When the Navy was assigned the support responsibility to several Department of Defense Commands by the Reorganization Act of 1958, the task of the ORD division was enlarged to encompass the study of those Command and Control problems as well as those of the Navy.

During the winter of 1958-59, a CINCPAC ad hoc committee was formed to study plans for the CINCPAC Operations Control Center taking into account the effects of the Act of 1958. Members were representatives of CINCPAC and his component commanders, BuShips, CNO, Taylor Model Basin (ORD) and various prominent computer industry leaders. From this committee developed the Kunia Coordinating Group (KUCOG) to assure coordination between the many technical and operational groups involved in the development of the OPCONCENTER [4].

Some of the ORD analyses indicated a beneficial use of computers in the Command and Control system. Commander-in-Chief Pacific, as the commander with number one priority, received an interim computer (IBM 704) so that operational studies could be made and procedures worked out. The requirements for a Command and Control computer system continued to grow and with it the overshadowing need for centralized control to assure at least Navy-wide compatibility with fond hopes of

services-wide abilities of interchange of data automatically from one computer complex to another [7]. To this end, the Chief of Naval Operations established a field activity commanded by one of his own staff officers and peopled initially with the personnel of the Model Basin who continued to develop their original models. On December 1, 1961 the functions, development, concepts, and personnel of the Operations Research Division of DTMB were transferred to the new organization, Naval Command Systems Support Activity (NAVCOSSACT). The scope of the job confronting the new activity was not only to continue the job commenced by ORD for CNO, CINCPAC, CINCLANT, CINCPACFLT, and CINCLANTFLT but also to start the system analysis and design for a "phase II" computer complex of several computers functioning as an entity that had been developed by the Bureau of Ships as the prime controller of the procurement of computer hardware. In addition, the physical facilities of NAVCOSSACT had to be created from shop buildings at the old Weapons Plant in Washington, D. C.; a large number of billets for additional personnel defined; and then the organization staffed with trained personnel, both civilian and military. The Naval Command Systems Support Activity mission is stated in part:

> ... Support the Chief of Naval Operations, Secretary of the Navy, Secretary of Defense, Joint Chiefs of Staff and Commanders of major commands in the development and implementation of Navy-sponsored command systems, including systems applications, techniques, standardization, evaluation, integration, testing and continuing programming; to provide such support in direct response to requirements determined by the Chief of Naval Operations or higher authority.

While the use of computers is not explicitly mentioned in this mission, the application of automatic methods is acknowledged as a necessary feature of modern Command and Control techniques.

3. Integrated System Concept

In order that orderly methods can be applied to an automated data processing system, the overall system concept must be defined. The integrated system includes not only the automated portion of Command and Control but also the human elements of a command. It is the man; the machine(s); and the vital man-machine relationship which compose an integrated system of a command. In addition, there is a man-machine relationship up the chain of command which must be considered for the entire integrated system concept. While each command must have its own integrated system, tailored to its needs, there must exist a similar relation between the various Command and Control systems which contributes to the total military Command and Control network.

A somewhat hardware oriented definition of the automatic data processing system for a command can be stated as:

> An automated processing system for Command and Control is a system of computer hardware and "software",[1] together with designated peripheral equipments such that the complex functions in a self-imposed environment which is receptive to priority designated commands (inputs) in a manner that highest priority commands are accomplished before lower priority commands regardless of the order of the queue. The master control of the complex's environment enables any of the contained procedures such as file creation, update, retrieval, program compiling and debugging, existing program revision and compiler revision to be accomplished within the system with a minimum of human operator intervention and will continually communicate with the operator, relating state of processing, requesting data insertion from specific equipment and other external actions required to bring each task to its satisfactory completion.

Portions of this definition which appear obscure at first reading

[1] The term "software" is used to define the computer stored programs and is usually used in conjunction with the term "hardware" which identifies the actual computer and its physical equipment.

will become clear with the examination of later sections of the thesis. While it furnishes the major guide lines for a computer system design it does not reflect the process of command decision nor the man-machine relationship which composes the <u>integrated</u> system. A commander cannot concern himself with the manipulations which the personnel associated with an automated system go through. Similarly, he is not concerned with the system itself except that he justifiably expects the output to be the best basis for the decisions he must make.

The coming of automation has spotlighted many of the problem areas of a large command. A large command staff, using manual or limited semi-automated processes of data collection, filing and retrieval, tends to become segmented into the various operational areas such as intelligence, logistics, operations, communications and others. This in itself is a feasible staff organization but discrepancies between the many overlapping files of material are not immediately apparent. When these files are automated, it is often found that supposedly duplicate data in several files are not compatible. There are differences because of mistakes, variance of opinion when raw data is evaluated, varying update cycles and varying file procedures. It is a responsibility of the computer and operations analysts as well as of the commander and his staff to ensure utilization of the proper procedures in data collection, correlation, verification, reduction and filing. Improper procedures are immediately discernable when the automated data processing is utilized and can lead to breakdown of the processing cycle. Many solutions of problems through the use of mathematical models have proven satisfactory when tested on carefully

collected input parameters. However, it has also been demonstrated that they can furnish completely erroneous and fallacious results when the input data deteriorates.

The organizational composition of the military initiates constraints upon the system. A useful automated data processing system to Command and Control must be responsive to the particular command it is to service and contain the potential of providing data to those outside the command in the manner best suited to them. A command, being a dynamic rather than a static structure, presents uncertainties in the prediction of its needs. Below are listed the major variables within a command that must be considered in system analysis and design.

a. The political and economic posture of the nation influences the commander's area of interest.

b. The actual structure above and below a major command is subject to change and the command position is rearranged with the change.

c. The geographic area of responsibility is subject to change.

d. As a commander is rotated, the command change in emphasis reflects the personality of the incumbent in respect to importance of data in collection criteria, reporting methods and presentation of data to form the basis of his decision making.

e. Higher command and collateral commands can change information provided and requested of a command without the approval of the commander.

f. Funding appropriations and the accompanying requirements of reports of expenditure vary annually.

g. Technological advancement in warfare and weapon systems place an increasing urgency on near "real time" responsiveness.

h. A commander's growing understanding of the technology of automated data handling will extend its range of application to new areas.

These variables make it virtually impossible to predict with reasonable confidence the data volume, desired input or output of the system, the reliance that will be placed on the system or the specific role it is to play to support a major command. The burden of flexibility is placed, therefore, on the system. System analysis and design must, where possible, compensate for the uncertainty of the above command variables which may be translated into system requirements as:

a. There must be a modularity of equipments composed of computer hardware, communcations equipment, input data links, output display and peripheral equipments so that growth and technological change may be accomplished by unplugging the outmoded and plugging in the newly developed components without major disruption or renewal of the system.

b. Major changes in processing should be possible with changes only in the operating procedures and computer program parameters. That is, extreme care must be taken to insure that programs are written to accommodate changes with the least amount of reprogramming.

c. The system should be able to easily adjust to changes in the command variables over their most probable range with little or no disruption.

d. Design should be flexible so that frequent changes which will

increase the range of the command variables beyond those expected can be accommodated with the least amount of disruption.

e. Processes must be capable of revision to accommodate improvements discovered through operational experience with the system. Learning is an iterative process and as the automated system is utilized, more desirable features will be found and implemented.

The following sections will discuss the details of such an integrated data processing system.

4. Analysis and Design

The Secretary of the Navy and the Chief of Naval Operations concurred with the report from the Institute of Naval Studies that a special centralized naval activity should be formed to provide the required system analysis and design [7]. Recall that the full time responsibility of this activity (NAVCOSSACT) is to provide the support for the automated data processing within the commands supplied by the Navy. There are several excellent reasons for placing this responsibility in one organization. The major purpose is to provide continuity between the large number of systems involved and the different nature of the computers, weapons, tactics and strategy that are included. It provides a common reference for information concerning system interfaces. A means is furnished for discovering and solving functional compatibility problems in advance of the time the systems must work together. Each separate Command and Control installation must have individual analysis and design to tailor the automated processing system to its particular needs. An operational command could not possibly devote a full time endeavor to such a task since his primary mission must be that of maintaining his operational readiness and posture through a continuation of existing procedures until automated methods can be proven and implemented. An outstanding practice to obtain operationally acceptable methods has been to combine civil and military personnel into teams where expertise in both computer technology and warfare doctrine can be united.

Analysis is not a one time effort that once completed is unsubject to change. It must be an evolutionary process which commences prior to the purchase of the computer or modular components and continues after

the initial implementation to maintain a system that is up-to-date with military and computer technological advancements.

The representation of the command staff in the analysis and development is a vital necessity. His presence not only provides the interpretation between the command's needs and the automated procedures to fill these needs, but the very fact that the command is included in the details of the analysis tends to belay the distrust in the delivery of an "unknown package". If the system is to function properly it must be designed to fulfill or supplement a command function which is either being done manually or is desired but not able to accomplish under existing circumstances. The staff representative can, with his familiarity with current practices, assist in the definition of each task and determine if an automated system is indeed performing in the manner desired. If through intimate association throughout analysis and design stages the user command is aware of the capabilities and limitations of the developed programs the system can become an integral part of the staff.

Recall that there are major variables within a command that must be considered in the design of the automated data system. To obtain a system which will accept a maximum variation of the variables and continue to function requires that programming methods and constraints be carefully established.

Before a single operational program which deals with a task directly can be designed, the system procedures which are within the framework of the system requirements stated in the last section must be developed. To have operational functions operate within a system, rules and specificiations must delineate the acceptable methods for

their design. Such rules and specifications deal with the use of standard subroutines, methods of functioning under control routines, application of utility routines such as error reporting and input and output requirements, the communication of a task with external devices and personnel, security procedures and the necessary documentation and training to support the task. These methods are considered of sufficient importance to devote a section to each of them.

After these system methods are defined, operational programs to accomplish specific tasks can be developed. These processes depend on the analysis composed of the following steps.

a. Determination of how a command decision is made.

(1) Discussion with command staff to determine problems.

(2) Analyze what each contributor does and why he does it. (This cannot normally be obtained by asking. The usual procedure is the step by step tracing of the necessity of the information; where it is obtained and how it is processed.)

(3) Determine the reliability of the information and its importance to a decision.

(4) Observation of current processes, exercises and military operations.

(5) Determine if the procedure is sound; if additional collecting or processing will enhance the decision making or if less data will provide as good a basis for the decision.

b. Determination of contribution that automated processing can make.

c. Design the process.

d. Test the automated process.

e. Determine the adequateness of the process in a simulated operational environment and within the control system.

f. Parallel manual practice with automated task for reliability testing.

g. Documentation and training.

h. Full implementation.

i. Continued review and revision.

Each of the above criterion represents a major subdivision in analysis and design and can be further divided to form a check off list to insure completeness of design development. A planned periodic review as well as "on demand" examination is required to insure currentness of the process.

5. Master Control and the Subsystem Executive

A primary consideration for an efficient computer system of modular hardware is the manner in which jobs are introduced for processing. Since a dynamic application can be anticipated, it would be unreasonable to plan that the tasks presented will be of a routine nature so that a fixed schedule of receipt of data or job assignments and a known periodic reporting requirements will makeup a satisfactory system. If the system is to be one of "action on demand", there are a great many housekeeping and setup procedures to be accomplished. Also if the system is composed of sufficient computers and peripheral equipment it is possible to process several different tasks simultaneously by the proper connections of various equipment to the various computers. Data and procedures stored on random access devices such as drum and disc files can be utilized by any of the tasks even though they are running at the same time with minor or no delay of a particular task.

If the number of jobs to be done at any one time were small and predictable, if the jobs were of equal priority so that none need be interrupted, if offline equipment were available, and if the input-output configuration were heavily multiplexed, then it might be possible to allow the data processing system to be completely controlled by the computer operator performing his functions by referencing run manuals and loading functional processing programs either from tape or card decks through manipulations on the control console.

The dynamic application of automated processing in Command and Control does not lend itself to methodical procedural organization where the computer operators can perform under routine working conditions. Conditions will vary radically with the requests submitted by

the users. If the operating personnel were to make all of the decisions for every job or task setup, it is apparent that:

a. The major portion of a computer day would be occupied with machine inactivity.

b. There would be a feverous chaos of personnel activity.

c. There would be deterioration and slow down proportional to the mental fatigue of the operator(s).

In essence, there are precisely the problems that a computer has been found capable of solving in accordance with preconceived criteria in less time than the human. This establishes justification for the need of an overall system monitor which will accept tasks, make decisions on how they can best be accomplished, request the files and data which are not available but required for processing, perform bookkeeping services and in general accomplish all of the menial tasks that grouped together and done by manual means would be exhaustive. The control system designed by NAVCOSSACT is called Master Control and is supplemented by a subsystem monitor called the Subsystems Executive which links Master Control to a specific task being executed.

Jobs and tasks are presented to the computer system in the form of Control Cards and to the operator in the form of instructions. Figure 1 illustrates the typical control cards required to initiate a functional process through Master Control. The computer programs which actually performs specific functions for the Command and Control users, like updating a data base, answering queries, and analyzing the operational feasibility of certain courses of action, are called <u>functional programs</u>. All of these functional programs operate under the control of a system monitor.

INPUT CONTROL CARDS FOR MASTER CONTROL

JOB CARD	Identification of Job, Priority, Classifcation Job Accounting Number
TASK CARD	Identification of Task Estimated Run Time Post-Mortem Dump Parameters
FILE CARD	File Code Number Type of Device and Use (Input, Output, Scratch) File Identification File Disposition
RUN MODIFICATION CARD	Octal Corrections Program-Required Parameters

Figure 1.

The control function is logically divided into two processes, Master Control and the Subsystem Executive.

a. Master Control Functions

Master Control is a programmed monitor and controller which is identified with the complete computer system and does the following within the system:

(1) Services job requests and provides the operator with a means to request the execution of a job. (A job may consist of one or more tasks.)

(2) Automatically combines a required complement of equipment into a subsystem capable of carrying out a task.

(3) Automatically provides task-to-task continuity for the tasks comprising a job and job-to-job continuity for the system.

(4) Maintains a File Directory relating physical tapes and files within the system.

(5) Provides centralized communication between the operator and the system.

(6) Provides interrupt capability of current processing for higher priority jobs.

The Master Control is composed of a set of processing programs and input-output subroutines used to maintain the tables and directories of system related information. The processing programs make the decisions concerning the actions to be taken in order to accomplish the overall processing. Figure 2 shows a schematic of the Master Control functions.

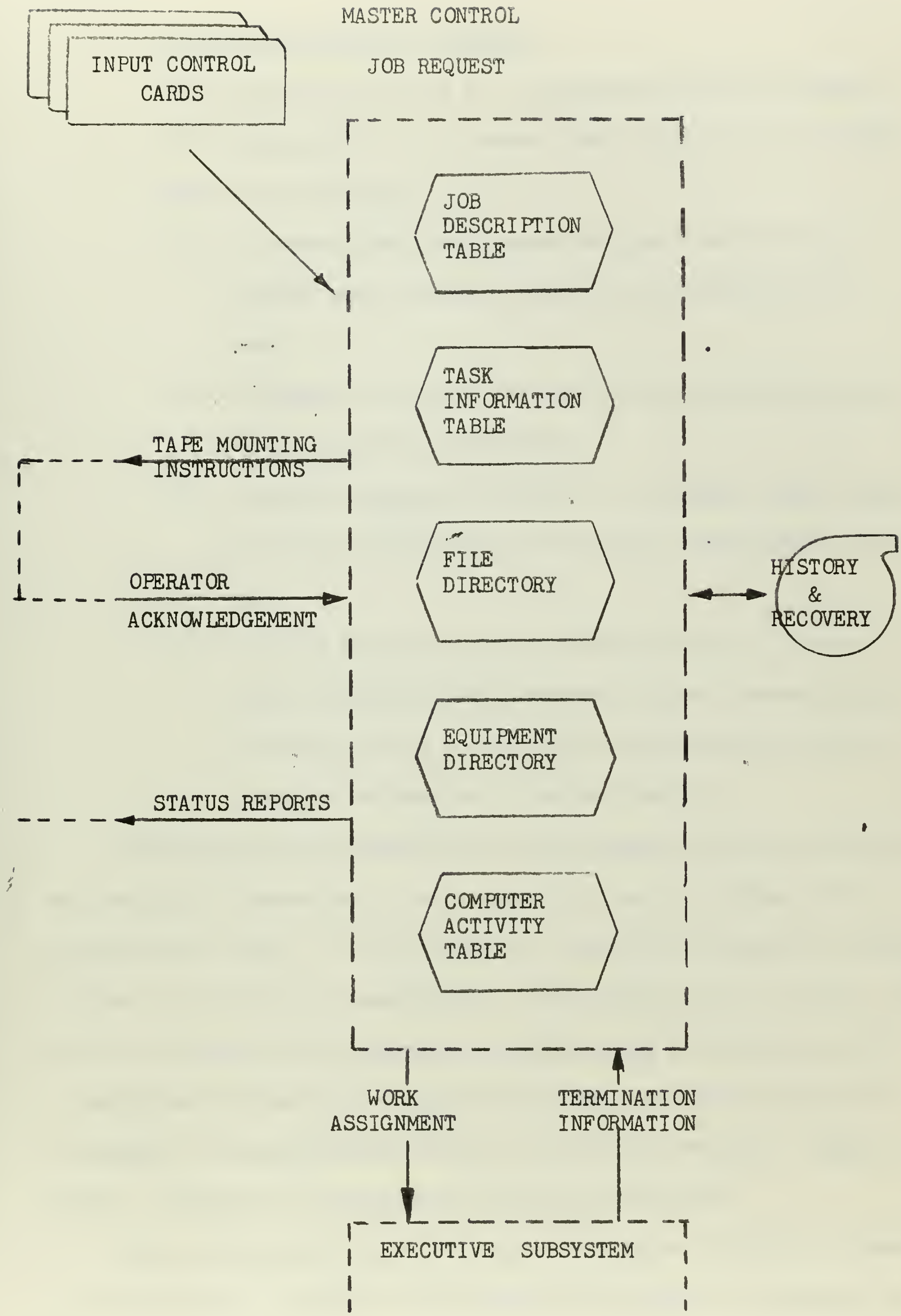
MASTER CONTROL
JOB REQUEST
INPUT CONTROL CARDS
JOB DESCRIPTION TABLE
TASK INFORMATION TABLE
TAPE MOUNTING INSTRUCTIONS
OPERATOR ACKNOWLEDGEMENT
FILE DIRECTORY
HISTORY & RECOVERY
EQUIPMENT DIRECTORY
STATUS REPORTS
COMPUTER ACTIVITY TABLE
WORK ASSIGNMENT
TERMINATION INFORMATION
EXECUTIVE SUBSYSTEM

Figure 2.

b. Subsystems Executive Functions

The Subsystem Executive is a programmed monitor and forms the communications link between Master Control and a single task under execution.

(1) Processes the input communications from the Master Control and provides a means for the execution of a task.

(2) Performs task initiation services in accordance with a preset operating environment.

(3) Provides programmer services on a "demand" basis dependent upon the particular functional requirements of the task.

(4) Performs task termination services such as, dumping memory, closing files, rewinding tapes, restoring any overlaid portion of the operating system and reports the task performance to Master Control.

The Subsystem Executive performs such operator service functions as checking to ensure the proper magnetic tapes are mounted on the assigned tape units. It then loads the functional program and transfers control to the task for execution. At the completion of the task, control is resumed by the Subsystem Executive which performs the task termination services such as rewinding tapes, post-mortem dumps (if requested) and communicates to Master Control the results. Figure 3 shows a schematic of the Subsystem Executive functions.

Upon initial start-up of the system the Master Control is loaded into the control computer. The operator is required to indicate, in reply to message request from Master Control, the equipment assignment

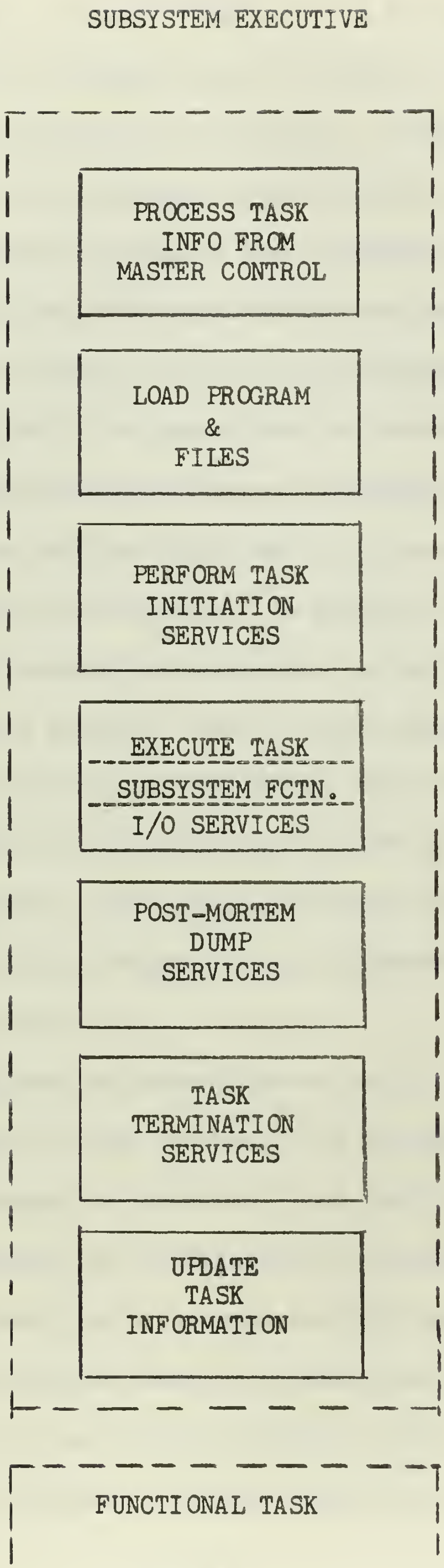
SUBSYSTEM EXECUTIVE
PROCESS TASK INFO FROM MASTER CONTROL
LOAD PROGRAM & FILES
PERFORM TASK INITIATION SERVICES
EXECUTE TASK
SUBSYSTEM FCTN.
I/O SERVICES
POST-MORTEM DUMP SERVICES
TASK TERMINATION SERVICES
UPDATE TASK INFORMATION
FUNCTIONAL TASK

Figure 3.

and the equipment status. Similarly, if during the processing day equipment must be withdrawn from the system for maintenance or repair, the current status must be re-entered. In this way, only those equipments which are in a running status will be assigned to tasks.

Master Control determines the sequence in which jobs will be performed. The criteria for sequence are the assigned priority of the job and the availability of files and equipment. The job queue is inspected repeatedly and tasks scheduled according to the criteria.

Two Directories are maintained by Master Control. The File Directory relates the physical tape reels (by number of reel) to the information files stored on each reel. In addition, the File Directory indicates which reels are mounted and available to the system and on what tape transport each is mounted. This file is updated upon the successful completion of each task in accordance with indications in the control card deck. The other Directory maintained by Master Control is the Equipment Directory. The entries indicate for each unit of equipment whether that unit is available for assignment or if already assigned, to what job or task.

Any communication between Master Control and the operator is either by signals on the console or by messages on the typewriter. Typewriter messages are signaled by an audio alarm to alert the operator.

Master Control as just described has been implemented in both the Command and Control system ashore and the National Emergency Command Post, Afloat in systems made up of different hardware and different compilers. It is one of the procedures used to standardize the use of the various computer complexes within the service.

6. Compilers in Data Processing

A compiler's purpose in the Command and Control system is to allow the construction and check out of programs in an efficient and rapid manner, make revision of programs easier and to provide a language that is the same regardless of the hardware configuration.

One of the most controversial subjects in the development of applications for the electronic digital computers has been, and will continue to be for some time to come, the translation of symbols and logic of the human into the language of the computer. It is next to impossible for man to comprehend the computer's strings of zeros and ones. The emphasis, therefore, has been placed on devising computer programs which will bridge the gap and translate man's symbols and descriptions into a workable binary description and the computer's output into a form readable by man. Varying degrees of sophistication have been used in programs to convert man's notation to instructions that are meaningful to the computer. The most common translator is the Assembler which allows symbolic coding in a one-to-one correspondence to the binary instructions and also alphabetic names for storage addresses. The more sophisticated translators are called Compilers and allow the introduction of symbology similar to that normally used by man. The compiler supplies a group of machine instructions for each symbolic phrase, thereby reducing the effort of the programmer. Experience has shown that the main benefit of a compiler is that it requires less writing and because the language is less complicated and more logical than assembler language, it allows more attention to the problem and demands less attention to the mechanics of programming. Unfortunately, there is usually a loss of efficiency in using compiler

produced programs. There are evidently uses for both the assembler and the compiler. In programs which will be written once and used over and over again, such as a routine to take a square root of a number, it will, in the long run, pay off to save as much computer time and memory space as possible. For these, then, a careful machine language program should be written. Where programs will be written and revised often there is much less expense involved if it is written in a compiler language which is both readable by man and machine and easily changed.

One of the earliest written compilers was FORTRAN and has become the most widely used. The FORTRAN language was written to conform to certain computer hardware and from its inception was restrictive and more hardware than user oriented. As are most compilers, FORTRAN was written mainly as an aid in the scientific use of the computer and does not contain the capabilities desired in data processing where alphabetic information is as important as numerical.

In 1958, a group of world-wide renown computer and mathematical authorities originated the Algorithmic Language, ALGOL, that was not related to any hardware and which attempted to fulfill all functions required of a compiler. Indeed, the specifications were so all inclusive that to date no hardware application has been able to perform as generally as the initial concept dictated. One of the features of an ALGOL compiler is that the compiler translates into a machine oriented language which is then assembled by an assembly program which utilizes the special innovations of the particular computer that is to be used. In this way the compiler is completely[1] free from the hardware and can

[1] Debatable.

be used on any that has an assembler to convert the machine oriented language into the binary code of the machine.

Two ALGOL type compilers are in use in the Navy Command and Control system. A modified version of JOVIAL, written by the Systems Development Corporation, has been adopted for the land based, large computer command centers and NELIAC, as prepared by the Naval Electronics Laboratories, is in use on the computers hardened for shipboard use. The use of NELIAC for the afloat Command and Control centers stems from its development for use on the same type computer in the Naval Tactical Data System.

There are two considerations for the measure of effectiveness of a compiler. One is the amount of time required to process a program in compiler language and reduce it to an operable program in machine language. The other measure is the efficiency of the machine language program produced. Of the two, the latter is far more important for programs which are written once and, thereafter, called in from library tape or from a binary card deck without recompiling. The former is the more important in programs which will be often revised or normally processed in a compile and run manner each time it is used. Needless to say, it is of an advantage to possess good measures of effectiveness in both aspects. Consideration must also be given to the ease of learning and programming in the compiler language. It is anticipated that functional tasks normally would be written in compiler language while some of the intricate, time consuming utility programs which will be called on by many programs will be condensed as much as possible by coding in assembler language.

JOVIAL, as modified for Command and Control, is labled J3 and is

oriented toward data manipulation as well as mathematical or scientific functions. It allows selection and operation by item name within defined tables without regard to computer word length. In this manner, packing and unpacking are accomplished without the programmer explicitly specifying the detailed operations. Tables or records may also contain various modes of data such as:

Binary Coded Decimal	- six binary bits or one byte to a character of alphanumeric data.
Integer	- binary whole numbers
Floating Point	- a form of storage and use that performs automatic scaling of the decimal point.
Status	- a method of assigning a number to a string of items thus giving them a rank structure.
Boolean Value	- true or false indicated by a one or zero.

Input and output operations may be programmed in JOVIAL and the compiler will originate proper requests and transfers to the Subsystem Executive to perform the data transfer. The JOVIAL compiler operates within the data processing system under Master Control and is called into memory in the same way as any other functional program, through use of Control Cards.

NELIAC, while in many ways similar to JOVIAL, does not function within the operational system. It is intended that programs for the afloat system will be completely programmed ashore and, that except for minor changes to the programs by octal correction insertion, the NECPA environment will be one for operational use only. If new NELIAC language programs must be compiled, it is necessary to do them outside of Master Control [9].

An important feature of any compiler is the error checking portion that will note syntactical inconsistencies and logical errors during the compiling process. To assist the programmer, JOVIAL provides a listing of the program with statements which contain errors tagged. In addition, a list of the table of constants used in the object program, a list of all tags, labels and preset constants and the translator produced dictionary is printed. If desired, the machine oriented language (assembler language) translation of the JOVIAL program is provided with a side by side listing of the machine language in octal. Upon request, dumps can be obtained of specified portions of memory. The dump may be requested in floating point, decimal or octal format. If preferred, the dump will be in instruction format.

7. Utility Programs

The control programs of the Command and Control automated processing system are the Master Control and the Subsystem Executive discussed in Section 5. The programs subservient to the system control can be divided into Utility Programs and Operational Programs. Utility programs are, in general, those programs and subroutines which perform services for any operational program which calls for them. Since they may be used by many other programs in an iterative manner, it is important that they take as little space in memory as possible and be as efficient as they can be designed. Because of these requirements, they are usually written in machine code and retained in their binary form in a random access or tape library which is always on call to both the control system and operational programs. They are, in effect, closed subroutines which though called upon many times within a task, need only exist in one place to which the task transfers for a specific action. The parameters are specified uniquely by the task on each transfer. After the utility program performs its functions, control is normally returned to the task for continuation. Abnormal functioning within any of these utility programs is reported to the Master Control of the system so that job termination can be performed and proper information given the user about the abnormal stop. Utility programs may in many cases again call up other utility programs.

Several utility programs, because they enable the control program to function properly, are mandatory. For example, any use of peripheral equipment by a task must be via utility input and output subroutines controlled by the Subroutine Executive. This allows Master Control to monitor priority jobs and cause interrupt when necessary.

Interrupt considerations are solely between Master Control and these input/output subroutines so the programmer need not concern himself with those procedures. The interrupt capability is "built in" to the operational program he writes merely by using the mandatory subroutines. Additionally, check sums and parity checks are made on all input and output data, the proper number of re-reads or re-writes are attempted when errors are encountered and non-recoverable errors are reported to the control system.

The Information Processing System is essentially a part of the Utility Programs of a Command and Control data processing system. This system is composed of two subsystems:

a. The File Maintenance System

b. The Information Retrieval System

The File Maintenance System is a flexible program with which files of data are either created or updated through the use of an operational program written in simplified macro-instructions such as;

MOVE, COMPARE, STORE IN, ADD, SUBTRACT

The Information Retrieval System enables a user to query the files created and maintained by the File Maintenance System in a manner that eliminates the necessity for him to have an intimate knowledge of the computer. Several optional types of output is available in readable format upon proper user request. It is also possible to obtain counts or summaries of queried items.

The general criteria under which the Information Processing System was developed is [8]:

a. Data used by Command Staff personnel must be structured into an OPCON Center Data Base in a formatted file structure for

use by operations, intelligence, logistics, and administration.

b. Data Base maintenance and recall of information must be accomplished easily for data structures which may consist of up to 200 files.

c. The Information Processing System must be used and maintained easily by OPCON Center Operations personnel, programmers, and operators.

d. The Information Processing System must be programmed completely in a Procedural Oriented Language (JOVIAL and NELIAC).

e. The general capabilities of the Information Processing System must be compatible with all Navy Command System data processing techniques.

It should be noted that because of the requirement that the Information Processing System be easily maintained (modified and revised) it is written in a compiler language. Since this system is extremely complex and recursive, any major change even in procedural oriented language should be attempted only by an analyst who is completely familiar with all facets of its construction.

8. Operational Programs

While the capabilities of the Information Processing System cited in Section 7 endows a user with an extremely flexible tool in data handling, there are many uses of military information which can not be made through such a generalized program. War gaming, estimation of damage and contamination and many other actions may utilize the data base of a military commander.

These specific type programs provide the commander with the scientifically developed alternatives on which he bases his decisions. Their input parameters may come from one or several of the data base files or from special input from other sources. Their processing and output are designed to meet the particular needs of the commander and it may be anticipated that changes will be necessary from time to time. For this reason it is particularly important that they be programmed in a procedure oriented language and that liberal use be made of comments and meaningful names and labels so that they can be easily understood and the changes made.

Most of the operational programs, primarily those which are used repeatedly, are placed on a library tape or random access device in binary form so that compiling is unnecessary each time they are called upon. It is evident that before a library program is changed that a modified version written in the compiler language should be completely checked out. It is normal practice to provide a user command with a master file in punch card form of all available operational programs. It is from this external file that reproduction is made to obtain a deck of the program to modify for testing and subsequent revision. After a thorough checkout, the old library binary program is replaced

or updated with the new version, the master punch card file deck is updated and complete documentation changes are made.

Many of the operational programs are composed of mathematical models and scientific procedures. It is not to be implied that a trained programmer can easily make changes to routines designed in a discipline with which he is not well versed except that it is possible for him to make minor revisions to output formats and the like. However, a person familiar with the methodology of the model, with little compiler training, can make modifications to the procedure oriented language program.

The necessity for military command staffs to comprehend, verify and make changes to technically sophisticated routines presents the requirement of including personnel on the staffs who are competent in formal operations research. This requirement exists with or without automated processing but the additional capabilities given command by the computer has emphasized the necessity of such billets. These personnel have a twofold job; that of maintaining the routines and that of bridging the interface between the technological and military professions. He must perform the translation from one discipline to the other and attempt to bring the technological and command languages to a common ground understood by both.

9. Input Capabilities

While internal computer speeds are extremely high with an execution of about 200,000 arithmetic operations per second, there is a considerable mismatch of this speed with the speed of input and output operations. These operations are executed at a much lower speed. The most efficient systems to date in this area are the single purpose computer systems operating with a set of specifically designated input signals in a real time system such as SAGE or the tactical "general quarters" program of the Naval Tactical Data System. This is not the situation which the Command and Control system encompasses.

The arrival of data at a Command and Control center can be in many forms varying from digital data transmitted by telephone lines or radio to reports in narrative form by mail. Digital data, if in the correct code for the command's computers may be entered direct, or collected in an off-line operation to enter directly when the decision is made to process the data. If the coding of the digital input differs from that required by the automated system, a conversion process is necessary to place the data in acceptable form. This translation is normally a one-to-one process and can be done in an automatic off-line operation with special equipment. Sometimes this special equipment is connected to the computer through a buffer so that sufficient data is collected for economical processing.

There has been widespread attention directed toward the automatic reduction of narrative data into a form that may be stored and retrieved by a computer system. To input the narrative information a transformation still must be made to digital form for the computer. Photoelectric and magnetic character reading has been developed for specific purposes,

but the state-of-the-art is not sufficiently developed for Command and Control application. The laborious human effort of extraction and formatting such material is the normal process which must be utilized. The insertion of the data is by transfer of the formatted material to punched paper tape or punch cards which are again transferred to magnetic tape off-line so that a medium speed of acceptance may be accomplished at the computer.

To maintain a "backup" capability in the event of loss of automated processing the military has insisted that incoming data be capable of furnishing "hard copy" intelligence to the human element as well as being able to be used in the automated system.

A method being used in the present system to eliminate the large manual translation effort at a Command and Control center is the design of formats to be used by originators that can be both read by the human and processed automatically by the computer. The punched paper tape of the teletype in Bardot code can be read into a computer at a comparably low speed of approximately 300 to 500 characters per second. Again, an off-line conversion of the paper tape input to magnetic tape can speed the on-line process. Often the formatted portions of incoming messages are extracted from the bulk of unformatted data by a special run on a small computer prior to submission to the system computer.

Automatic input data must carefully be checked for errors which occurred either at the originators or through garbles caused in the communication medium. The five level Bardot code does not allow for parity bit transmission and garbles are not immediately discernable by automatic means unless error checks are built into the formats. Error detection can be achieved by requiring insertion of check sums for

numerical data and multiple identification which can be verified and related by comparison with directories maintained within the automated system. Error detection slows processing considerably and a compromise is made to accept the minimum of errors so to speed the processing yet maintain a sufficient degree of accuracy in the files to present truly meaningful material to a command.

Input technology is an area that is under intensive research to improve the serious speed mismatch with internal processing. Its necessary interface with communications technology further complicates its development. Improvements may be expected in the next few years and with the automated system a modular one, these improvements can be incorporated.

10. Output Capabilities

A quotation by Captain Harry C. Mason seems to be an appropriate introduction to the problems in automated output requirements [10]:

> Effective information processing systems can perform routine functions, store vast data bases, search these data bases, arrange and rearrange data, select and update specific data groups, accomplish complex computations and comparisons in fractions of seconds. They can remember staggering amounts of information. All of this capability is lost unless the system's output can be coupled to a human, to command for choice or decision. This is where display is required. It is the "transducer" which links the manipulative power of the automated systems to the still more powerful human ability to perceive and judge.

The adequacy of an output medium has been the subject of much research. The President's Council of Scientific Advisors have found in many instances displays of unnecessary sophistication have been constructed, not because they are needed to depict a situation, but to enhance the status of the user. Recall, for example, the British war display during World War II where large horizontal charts the size of several rooms where used and beautiful, realistic models of ships and aircraft were pushed around and viewed from above. A general rule recommended by the council was that displays be limited to those which reflect the true situation (as it is known) without distracting frills. The Department of Defense Damage Assessment Committee found that a large display which required examination by portions because the eye could not span the display was much less effective than console displays of the same material on a screen that could be examined in its entirety.

Within the present state-of-the-art capabilities of displaying output there appears to be adequate forms to furnish the commander the information he needs. An important feature to provide for in the output of an automated system is the ability to query data and obtain the

replies at a station remote from the vicinity of the computer. There are several television type units designed and available that can be used for this. Few displays in Command and Control need "real time" updating and a moving picture type representation, however, they are not prohibited by the remote relay equipment. Hard copy documentation of the data provided a command is important for post-action evaluation. This is particularly true in simulation or war games where critiques after the exercise contribute to the advancement of techniques.

The area of display of output from automated systems is not a solidified area in Command and Control. It will be, for some years to come, a portion of the system that will change to fit the state-of-the-art and the desires of a commander.

11. Communications

Sections 9 and 10 on Input and Output Capabilities have hinted at the importance of the communications network to automated data processing in Command and Control. The currentness and accurateness of a commander's data base is dependent upon updating material furnished from beyond the geographic site of the computer system and the commander's staff. Communications have historically been a chronic problem of the military system.

The commercial development in digital data communications has largely been in the use of standard telephone and telegraph lines. The American Telephone and Telegraph Company believes that the volume of digital data traffic will probably be greater than voice traffic over phone lines by 1970. Standard telephone circuits have been adapted for reliable, serial data transmission for general use. Transmission rates of medium speed (75 to 2000 bits per second) are available through data-phone service. Data flow in a typical data transmission is shown in Figure 4.

The military has accepted the commercially developed procedures where possible, but the serious dependency on transmission lines which can be sabotaged makes it desirable to parallel the development in the medium of radio broadcast. It is also mandatory that encryption and decryption capabilities exist for classified data transmission.

Automated Data Processing increases the communications load as it has a voracious appetite for current up-to-date information. Communications facilities lag behind requirements; they become overloaded and saturated, creating traffic jams and intolerable delays. A possible solution is to reduce raw data at the source and submit it in standard formats.

TYPICAL DATA TRANSMISSION

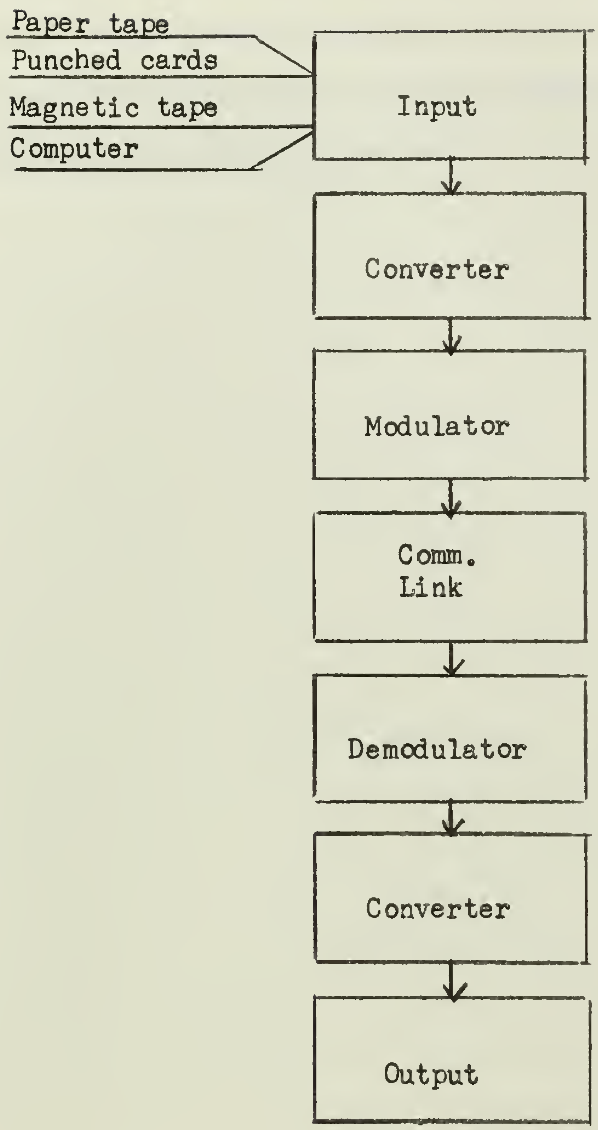

Figure 4.

The progress in digital transmission has been accelerated by the Naval Tactical Data System development where ships communicate from computer to computer by radio networks. Improvements will continue in present equipment and in development of multi-channel switching and data distribution modules.

12. Security

Automated data processing in Command and Control has brought with its augmentation its own security problems. In the past many of the classification procedures hinged on subjective decisions made by an originator of classified matter. All of these subjective criteria have not been possible to reduce to an objective criteria which can be determined by automated means. Often a collection of information, any part of which is low in security classification, is considered by virtue of presenting an overall picture of a situation, of much higher classification. Current Department of Defense instructions require that classified matter be automatically downgraded at specified intervals from its initial date.

In the files carried within an automated system, the best solution thus far has been to classify the file at a particular level and require that any information extracted from that file to carry the same classification. Within the generalized information retrieval system, capabilities have been incorporated to inspect each record of a file for its classification and inhibit retrieval of records whose classification exceeds that of the requester. This requires that each query state the highest level of classification desired from a file. The problem remains, however, for a human judge to determine whether a user has the authority to request certain classified information on a "need to know" basis or if he possesses the necessary clearance. The administrative burden also remains in the hands of the human to control the distribution and hard copy printing of data extracted from the automated system. In retrieval processing it is easy to report at the completion of a job that "there are 54 pages to this classified report" but it is

virtually impossible to number each page "1 of 54, 2 of 54", etc., before the total number of pages are known. Clearly, special regulations and practices must be adopted for security measures in Command and Control centers. The requirement that everyone involved be cleared for all data, while it might seem to eliminate problems, endangers the security of a system by allowing access to those who in essence do not have a true need to know.

Classification and release of classified information is a command prerogative. The commander retains the release authority for data originated with his command to any other command. This necessitates a review of queries by those outside of a command prior to the issuance of a reply. While the time will come when queries may be sent from computer to computer, it is obvious that except in particular prearranged carte blanche approved communications that human interrupt for security review will be necessary.

Security control cannot be passed completely to the machine. To maintain security the person with the responsibility will have to retain the control. Files can be classified, records can be classified or even individual items may carry their own classification and each of these may have their own timeliness date, however, the decision to downgrade, re-date, or upgrade will continue to be controlled by the responsible authority.

The automated data processing facility and equipments also have their unique security problems. Each facility must be a secure area where only authorized emission of classified data is allowed. Each electronic equipment must be completely checked against unshielded electronic emissions which might send out intelligent data to an

unauthorized receiver. Devices such as flexowriters, printers, and computers themselves have been found necessary to shield. Digital data on magnetic tapes and cartridges, punched cards or paper tape while not immediately identifiable as containing classified information must be rigidly controlled. A common practice is to use colored reels of magnetic tape; each color representing a different degree of classification. Once such a system is established, all reels of that color are considered classified when introduced to the system, whether they are blanks, outdated or degaussed (erased). Normal destruction policies govern their disposal. Cards and printer paper with pre-printed classification have been found acceptable but again close control must be maintained to be sure that they are used for matter of proper classification.

The analysis and design of administrative and operational procedures for proper control of classified matter in the Command and Control system is a joint responsibility of the automated systems analyst and the command who must implement them. These procedures form a part of the integrated data processing system.

13. Documentation

Ask a computer programmer what part of his job is the least interesting. He will, in all likelihood, reply the final documentation of a project. Yet, to create a program that will be useful to someone other than the programmer, complete documentation is a vital necessity. Documentation can be separated in content into three primary areas by the purpose for which each is used.

The first collection of documentation is the complete technical write-up of the program. This is important data for continuity in the turnover of the continuing analysis and review from one person to another. A unique identification should be assigned each program. This might consist of a number and a title, the name of the programmer, the date completed and the last modification. The purpose of the program should be stated in one or two short paragraphs. The method or logic that has been followed should be given in a verbal description which augments a flow diagram. A sheet summarizing the computer operating instructions, including labels, description of the file data on which it operates, subroutines required, peripheral equipments used, average run time, switch settings and any error or special procedures should be included. An up-to-date listing of the program with any changes made after the program has been checked out, listed, signed and dated will help spot future difficulties. A programmer can beneficially include suggestions for future changes and warnings about making certain assumptions of the program's performance. If the program produces any output, a sample of each type should be part of the documentation. This set of documentation forms the official file of a program and administrative procedures should prohibit any changes to an existing program without submission

and approval of the changes also to the official file.

Portions of the complete write-up extracted and placed in an operations manual provides the operator of the computer the set up requirements. This should consist of the minimum necessary data in a quickly discernable form that relates machine set up, console switch settings, on line instructions to expect during processing, tape units required and any error correction procedures. When operating under Master Control all of this information normally is furnished the operator by on-line printouts, however, some of the computer commands may need explanatory notes in the manual.

The user who requests various runs from the automated processing system must have available the procedures he must initiate to obtain desired reports. A Procedures Manual for various processing runs exhibits input documents and formats with instructions for their preparation and transmittal. It also displays output forms and reports and an explanation of the contents, codes, and limits. Specific procedures for normal information retrieval capabilities as well as special capabilities of the particular program are explained.

The administrative regulations implementing the procedures for documentation must be thoroughly understood by the personnel responsible for providing the material. Since documentation is considered laborious to most, only by careful followup action can it be brought to a satisfactory level which is necessary for continued proper computer operations.

14. Personnel and Training

The automated data processing in operations control centers levies a requirement to have personnel within the center and also in the command staff which are trained in the concept, in the system and in the operational procedures and the technical methods of programming. This is not to say that all of these attributes must be mastered by any single person, however, those in management positions must be familiar with them all and thoroughly trained in the concept and system capabilities. The use of automated data processing has not reached a universal military use where the incoming personnel to a command may be expected to have a working knowledge of the system. In the future, when such experience can be expected in a large percentage of a command's personnel input, these people still must be oriented to the particular idiosyncrasies of a command's system.

To hold the "dead time" of personnel to a minimum; that is, to provide them with a capability to function and carry their portion of the command load in the shortest time, a formal training program is a necessity. Such a program cannot be a single set of topics which all incoming personnel receive. Special lectures of orientation must be planned for the senior staff officers; particular emphasis placed on the system's file content and user's procedures for the personnel who desire information from the system; programming methods taught the command's program maintenance personnel, and the machine operators taught the operational procedures necessary to run the computer complex.

The formal training is augmented by on-the-job training so that the practices and theories taught may be demonstrated and proficiency gained through use of the new tools provided. Since many of the

operational procedures involve a collection of complicated processes, simplified procedures which train a person in a singular process can be an aid to instruction. With such, it becomes apparent that even though a computer complex is considered purely operational, there needs to be a portion of its time devoted to the training of inexperienced personnel. This can only be overcome if separate facilities are made available for this training. Until an operational complex becomes nearly saturated with its primary purpose and cannot be enlarged less expensively than a separate training facility can be instituted, it appears that training time schedule on the existing complex is the best recourse.

While training of computer center and command staff serves to preserve the continuing functioning of an existing automated data processing system, it does not provide the expertise necessary to continue the evolutionary change toward a better and more complete system. Major revision and new automated system programs and functional programs are provided by the central support organization, NAVCOSSACT, either by their in house staff or through contract to private organizations capable of performing the work. The in house staff is composed of both civil service and military personnel which perform analysis and design as well as the actual programming. These personnel must be trained and in some instances, educated in order that they can discharge their functions. Not only must these people be complete masters of the automated system, and familiar with the command problems, but they must be competent in operations analysis techniques which encompass most all of the scientific disciplines.

To date, with the exception of a few mathematical models, assistance

in data collection, filing and retrieval has been the major contribution of the computer to military Command and Control. As acceptable data processing techniques are implemented, emphasis will shift to automated assistance in the decision making of a command through the use of mathematical and statistical models. These models can, through scientific reasoning, provide alternate feasible solutions, test the sensitivity of input parameters to determine their relative importance and indicate the probabilistic certainty of success or failure of an action.

Now is the time to prepare personnel to construct new acceptable logical models for decision making. Since most of the disciplines are formal and a good foundation may be found in the courses offered in leading advanced educational institutions, it is there that the basics should be obtained. After basic education is accomplished, additional instruction relating the formal subjects to practical application can be provided through an educational program within the organization. Topics which are important in the creation of mathematical and statistical models include:

a. Set theory and Boolean algebra for the basic understanding of computer logic and data handling.

b. Matrix theory as a powerful tool in computer solutions to simultaneous equations, maximum and minimum problems, linear programming and statistical evaluation.

c. Probability as a prerequisite to statistical methods and the development of random variables, distribution functions and stochastic processes.

d. Statistical methods to replace personal intuition with

scientific reasoning in testing hypothesis and calculating efficiency.

e. Specific instruction in the use of Monte Carlo techniques and the creation, testing, and restrictions of various random number generators.

f. Linear programming, its uses and restrictions.

g. Queueing Theory.

h. Dynamic programming, its uses and limitations.

The above list is not by any means considered exhaustive and many of the other scientific and mathematical fields are important.

Often, rather than train existing personnel, they can be replaced by others which already have a firmer foundation in the formal subjects. The military has increased the output of postgraduate personnel considerably in the past few years and it appears that the trend will continue. Not only are these military personnel being given the necessary formal education but they are familiarized with computers and many have past operational experience which can prove invaluable in the analysis and evaluation of computer applications to warfare management. Operations analysis billets have been created in both the shore establishment and the fleet. There is no reason, therefore, why an officer with a sub-specialty such as operations analysis can not spend most of his career in areas where his specialty can be applied.

Enlisted personnel in the ratings of Machine Accountant and Data Systems Technician compose the necessary hardware operating personnel. Many of the Machine Accountants have proven to be excellent programmers and can be of great value in major programming effort as well

as in program maintenance and modification jobs. Navy wide examinations for advancement in rate presently require a broad knowledge of a large number of equipments of various manufacture rather than testing in the particular field with which the man is familiar. Adjustment is needed to allow enlisted personnel in these ratings to advance in rate through his proficiency in the Command and Control system.

The training and education of personnel, both military and civil service, is a vital contribution to the proper functioning of the integrated Command and Control system.

15 The Future of ADP in Command and Control

Automatic data processing must continue to expand and improve in the military Command and Control system. The computer, while a major hardware component, is itself a relatively small part of the complete operation. Automatic data inputs from remote sources should be expanded so that the manual input effort can be reduced. Data links with high degree of accuracy and transmission speeds approximating those of the computer are needed. Man-machine relationships are of the greatest importance and can be assisted by equipments which provide for interrogation of the computer's memory and provide adequate displays. These equipments for the sophisticated applications of Command and Control are almost non-existent today and must be developed.

The major portion of development effort in the Command and Control system has been the analysis and design of a flexible, modular automated data processing system. While continued analysis will always be necessary in this region, the commander requires more and more assistance in making his decisions. That is, not only the presentation of data necessary for a decision, but recommended alternatives developed through scientific methods must be offered to the ultimate decision-maker. Computerized models are the only methods which can assimilate the large data bases, explore the thousands of alternate actions possible and display the feasible solutions to the command within an acceptable time frame. Relatively few such models have been developed for the Command and Control system.

Only the largest commands have thus far been provided with automatic data processing systems. Intercommand communications between computer systems have only received initial consideration. In the

future the systems of the complete chain of command must be implemented and joined in a compatible network.

Many of the eminent developers of computer logic feel that it will be possible in the future to construct computer problem-solving programs whose behavior is selective rather than just rapid. Humans achieve this selectivity through heuristics - principles that, on the average, contribute to reduction of search in problem-solving. From the formalization of heuristic techniques, there can possibly come such problem-independent procedures as generalized problem-solvers which can be applied to many content areas [6].

This concept is extended to unlimited possibilities under the heading of "artificial intelligence" or the simulation of the human by machine. As more is learned of the electronic and chemical processes by which the human brain functions, the closer may they be simulated by an electronic digital computer.

Even without immediate breakthroughs in the above area of artificial intelligence, there are many areas in which improvement can be registered. The possibilities of results from the man-machine systems have just begun to be investigated.

The necessity to deliver to the decision maker those things which cannot be provided without automated data processing has established the continued and ever increasing need for such assistance.

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